Optimising the operational parameters of a spherical steriliser for the treatment of oil palm fresh fruit bunch

D Kumaradevan[1], K H Chuah[1,3], L K Moey[1], V Mohan[2], W T Wan[2]
[1]FOSTEM, INTI International University, Nilai, 71800 Negeri Sembilan, Malaysia
[2]BELL Management Sdn. Bhd., Subang Jaya, 47500 Selangor, Malaysia

E-mail: kenghoo.chuah@newinti.edu.my

Abstract. The extraction of crude palm oil (CPO) begins with the sterilization of oil palm fresh fruit bunch (FFB) in a pressurized, saturated-steam chamber. Sterilization loosens the palm fruits from the stalks and deactivates the free fatty acid (FFA)-producing enzymes. Operational parameters affecting the quality and yield of CPO from an industrial spherical sterilizer are studied at a palm oil mill. The factors are the ripeness of FFB, the number of days before treatment of FFB, and the number of pressure peaks applied in the sterilization process. The results indicate that the degree of ripeness of FFB is the most important parameter affecting the quality and yield of CPO. Ripeness is graded based on the fruits' colour and the presence of loose fruits. Over ripe FFB that goes for the sterilization process has higher FFA content in CPO and more oil loss to the condensate chamber. The spontaneous reaction on FFB due to accumulation at the loading ramp also gives rise to higher FFA content. Oil loss to condensate chamber is reduced using a two-peak sterilization technique for over ripe FFB; the peak refers to the pressure level of stream after a flushing and refilling cycle. Overall, the generated solution improves the quality and yield of the palm oil mill.

1. Introduction

Crude palm oil (CPO) is a globally traded commodity extracted from the flesh or mesocarp of oil palm fruit. The extraction begins at a mill with the sterilization of fresh fruit bunch (FFB), where each bunch contains more than a thousand individual fruits and all bunches are cooked in a pressurized, saturated-steam chamber. The purposes of sterilization are to detach the fruits from the stem, to stop the enzyme reaction that caused free fatty acid (FFA) in the oil, to assist in the breaking of oil cells in the mesocarp, and to condition the nuts for subsequent cracking [1]. As sterilization is the first step in the production of CPO, any problems at this stage will propagate downstream, affecting the successive processes as well as the overall yield and quality of the oil. For instance, an insufficiently cooked FFB may have some of its fruits intact, preventing them from being stripped, or an excessively cooked FFB may have rendered some of its fruits too tender for machineries, creating chances of ripping and causing an oil loss. Sterilization is therefore vital for CPO extraction [2].

[3] To whom any correspondence should be addressed.

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This paper is a report to analyse the operational parameters affecting the quality and yield of CPO from an industrial spherical sterilizer. The objectives of the study are:

- to determine the FFB ripeness and to control the FFA level,
- to identify the factors affecting the sterilization process,
- to identify the quality of fruit collected at loading ramp without processing, and
- to provide a solution to overcome the factors affecting the sterilization process and the fruits collected at the loading ramp

Section 2 introduces the operational parameters of spherical steriliser. Section 3discusses the experiments, results and discussions. Section 4 is the conclusions.

2. Operational parameters of spherical steriliser

With the objectives of improving yield and quality of CPO, the independent parameters are the number of pressure peaks applied in the sterilization process, the ripeness of FFB, and the number of days before treatment of FFB. The dependent parameters are the percentage of FFA in oil and the percentage of oil in condensate. The controlled parameters are the steam conditions and the current sources of FFB.

2.1 Sterilization of fresh fruit bunch

Sterilization is performed in a chamber with saturated steam at an elevated pressure. Initially, air is removed from the chamber with steam together with any condensed water. Steam at a lower density can displace air from the top of the chamber, forcing the air to leave at the bottom. Once the air is removed, the pressure in the chamber is raised to a set pressure to start the sterilization process. The process produces low quality steam-water mixture as a result of heat transfers, and the mixture is therefore flushed and replaced with new steam to renew the heating. The process utilizes new steam at 30 – 40 psig and the duration of sterilization is between 75 and 90 minutes; current industrial practice has dropped the time to about 60 and 70 minutes. Overall, sterilization generates about 36% of the total waste water in the mill [1].

Conventional sterilizer is a long cylindrical chamber with a side loading door and rails running all the way into the chamber. A number of carts filled with FFB can be pushed into the chamber for sterilization, and as easily be pulled out at a later time. Steam is piped into the chamber once the chamber is filled, thereby heating both the carts and the FFB.

The mill in this study uses the approach of a spherical sterilizer, a 25 cubic meter enclosure with a top opening for filling the FFB and a bottom condensate drain. The drain is covered with a strainer to block FFB from slipping through the waste water drain. The spherical chamber, pivoting on two horizontally aligned shafts to the chamber's centre, can be rotated 180 degrees to pour out its contents. Steam is supplied in a concentric pipe through each anchoring shaft. In general, spherical sterilizer is more efficient than conventional sterilizer, as the process can be scaled up and transporting carts are not necessary.

In either case, flushing and refilling expend steam energy, which lead to more waste water. Each steam change cycle is called a peak, defined as an increase in chamber pressure until a maximum followed by a decrease in chamber pressure. In practice, two-peak and three-peak sterilizations are common, and the tests in this paper are conducted with these two configurations.

Steam sterilisation is not the only way of treating FFB. The other methods are air sterilisation [3] and microwave sterilisation [4]. Hadi et al explores direct sterilisation with conventional oven, and the result is comparable to steam heating, if not better [3]. Dry heating avoids the generation of waste water, which water ends up as palm oil mill effluent if mixed with oil and dirt in the process.

Similar result is obtained for microwave sterilisation. In addition, microwave irradiation can sterilise FFB in less than 17 minutes with relatively low power while maintaining the CPO quality [4].

2.2 Classifications of fresh fruit bunch

FFB arrives at the mill in several different conditions: under ripe, unripe, ripe, over ripe, empty and rotten. The quality of FFB affects the yield and quality of the oil produced and is a major factor in the course of optimising the sterilization process [4]. Local plantations in Malaysia practice manual grading of FFB. With human vision, the colour of fruits is the simplest and most direct way of assessing the quality of FFB, although automated grading with machine vision has been developed recently. Jaffar et al. reports an automation method to systematically grade FFB into ripe and unripe grades. The method is a prove-of-concept that correlates colour to ripeness with the use of colour coding and computerized image processing system [5].

Table 1. Classification of FFB into ripeness categories based on mesocarp colour and pattern.

Ripeness	Colour	Loose fruits	Sample
Over ripe	Orange	>10	
Ripe	Orange-red	~10	
Under ripe	Red-purple	<10	
Unripe	Purple-black	<1	

A more comprehensive system for automatic grading, developed by Makky and Soni, shows that machine vision can perform up to 12 tons of grading per hour [6]. The system classifies FFB into 6 categories starting from unripe to over ripe, as well as rejecting empty and rotten bunches with success rate of over 93%. Field tests conducted indicate that just minor adjustment is required.

In this paper, manual grading is performed at the mill for experimental purposes. Random samples of 80 FFB are graded based on mesocarp colour and presence of loose fruits. The classification is divided into unripe, under ripe, ripe and over ripe as shown in Table 1 below. Based on the ripeness distribution sampled, an assessment is made to ascertain the effect of ripeness on the percentage of FFA in oil and the percentage of oil in condensate. For example, the assessment may show that a distribution with more over ripe FFB lose more oil than a distribution with more under ripe FFB.

2.3 Number of days before treatment of FFB

Delay in processing of FFB is sometimes unavoidable primarily due to fluctuations in supply. Storage of FFB before processing is thus a standard practice to buffer away the uncertainty, but the practice is detrimental to the quality of CPO. Zu and Bani notes that stored FFB have higher FFA content than freshly harvested FFB, and the content depends on the duration of storage [7]. The reason is the enzymes in the FFB after harvesting start attacking the mesocarp, making the flesh soft over time with the decomposition of oil and the production of FFA. The FFA content reaches unacceptable level by 72 hours after harvesting.

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2.4 Measurement of FFA in oil

FFA is an undesirable content of CPO, and the target is to reduce FFA to below 5%. A simple chemical analysis can be performed to check the content in CPO. The analysis, following MPOB test method [8], mixes 6ml of CPO with 50ml of isopropanol and 3 drops of phenolphthalein in a solution. After boiling the solution, the percentage of FFA is estimated from the amount of sodium hydroxide (ml) required to turn the solution red times the ratio of its concentration and the sample volume.

2.5 Measurement of oil in condensate

Oil in condensate represents the oil loss with waste water. The percentage of oil in condensate is directly measured from the collection tank. The target is to reduce the percentage toward 0%.

3. Experiments, results and discussions

The spherical steriliser is a piece of industrial equipment in full operation at the mill. As such, we adhere to all practical restrictions in performing the process optimisation. Testing and improvement activities are carried out only when possible, and the data collected may not always be complete. In total, six cases of tests are conducted at the mill, and each case represents a single sterilization. Of the six cases, manual grading is performed for three of the cases to assess the effect of ripeness on the FFA and oil loss contents as well as the effect of number of sterilisation peaks on the same two contents. The other three cases assess the effect of storage on FFA content.

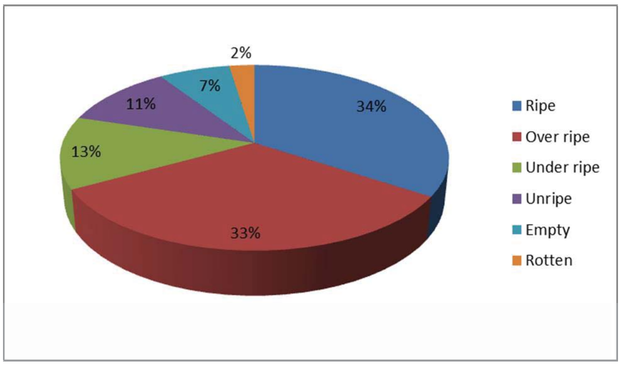

Figure 1. A typical distribution of the types of FFB sampled.

Figure 1 shows a typical distribution of the types of FFB sent to the mill. It is clear from the pie chart that two-third of FFB sampled are either ripe or over ripe, amounting to, respectively, 34% and 33% of all FFB. It is known that these FFB are where most of the oil is derived. In the remaining one-third of FFB, 13% is under ripe and 11% is unripe, respectively, whilst empty FFB (7%) and rotten FFB (2%) account for the rest of the samples. The mill acquires FFB from planters in the vicinity, and thus efforts that dissuade planters from harvesting unripe FFB can reduce these percentages. An effort for example is a system that rewards planters with better prices based on a track record of quality produce.

Table 2. Data collected on site for six test cases for the sterilising process.

Case No.	1	2	3	4	5	6
% over ripe fruits	25	17	58	-	-	-
% ripe fruits	34	48	20	-	-	-
Peak pressure (psig)	35	35	40	35	35	35
Process length (min)	67	67	55	67	67	67
No. of peaks	3	3	2	3	3	3

No. of days stored	-	-	-	2	3	2
% FFA	4.8	3.7	4.3	4.7	5.8	3.7
% Oil	4.6	2.9	3.9	-	-	-

Table 2 summarizes the values and parameters applied to each test case at the mill as well as the respective results. The results indicate that the degree of ripeness of FFB is the most important parameter affecting the quality and yield of CPO. Case 1 and case 2 show that the percentages of FFA and oil decrease with the percentage of over ripe fruits. Percentages of FFA are both below 5%, but the percentage of oil of the first case is the highest observed at 4.6%. It is clear that over ripe FFB that goes for the sterilization process has higher FFA content in CPO and more oil loss to the condensate chamber with the standard three-peak sterilisation process. To test the matter further, a random sample with over 58% of over ripe fruits is treated with a shorter, non-standard, two-peak sterilisation process. The result as case 3 indicates, the oil loss to condensate chamber is reduced to 3.9%. Figure 2 shows the physical appearance of over ripe sterilized fruit. Its physical appearance which is light brownish indicates that it is well sterilized. From these assessments, three-peak sterilization is optimum for ripe bunches and two-peak sterilization for over ripe bunches.

Figure 2. The physical appearance of over ripe sterilized fruits in Case 3.

To assess the effect of storage on the percentage of FFA content, case 4 and case 5 demonstrate that as the time of FFB storage grows from two days to three days, the percentage amount of FFA surges as well, from 4.7% to 5.8%. Clearly, FFA percentage of over 5% is unacceptable. Nevertheless, an interesting factor discovered is that if the stored FFB are spaced out in the open and left for two days, the FFA percentage actually drops to 3.7%. We theorize that the spontaneous enzymatic reaction on FFB to FFA is due to the packed accumulation at the loading ramp, as shown in Figure 3. By simply spacing out the FFB, enzymatic effect is reduced.

Figure 3. The FFB loading ramp at a mill.

4. Conclusions

In conclusion, the solutions to overcome the factors affecting the sterilization process and the fruits collected at the loading ramp are to source the fruits with consistent quality and to properly distribute the fruits at the ramp, conceivably with automation. As the degree of ripeness of FFB is the most important parameter that determines the quality and quantity of the extracted oil, proper grading can ensure that consistent process are always applied for different quality of fruits. To further increase the quality and quantity of oil production, automated handling of harvested fruit should be considered for preventing excessive delays at the ramp. A future study should be conducted on practical ways to incentivize the planters whereby only ripe crops are harvested and sent to mill for processing.

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